REMARKS

A substitute specification and abstract are hereby submitted to conform more closely to idiomatic English. No new matter is added. An inadvertent error occurred in the marked up version at page 7 line 9 and is corrected manually.

Applicants respectfully request that the preliminary amendment described herein be entered into the record prior to calculation of the filing fee and prior to examination and consideration of the above-identified application.

If a telephone conference would be helpful in resolving any issues concerning this communication, please contact Applicants' primary attorney-of record, Curtis B. Hamre (Reg. No. 29,165), at (612) 336.4722.

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SPECIFICATION

TITLE OF THE INVENTION

METHOD FOR FORMING MULTI-LAYER WIRING STRUCTURE

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

The present invention relates to a method for forming a multi-layer wiring structure on a semiconductor wafer or on a glass substrate.

DESCRIPTION OF RELATED ART

In general, a device being formed on a semiconductor wafer or on a glass substrate has a multi-layer wiring structure~~, with which wiring of lower and upper layers~~comprising a lower wiring layer and an upper wiring layer which are electrically connected through a so-called via hole.

~~And~~However, ~~under~~ in such ~~the~~ a multi-layer wiring structure, ~~in which~~ when only an insulating film ~~or layer lies~~is provided between the upper wiring layer and the lower wiring layer, an unevenness of the lower wiring layer ~~still remains~~will be present on the surface of the insulating film ~~or layer~~, and ~~it causes cut down~~breakage will be caused in ~~of~~ the upper wiring layer which is formed on the uneven surface by a CVD method. Therefore, technologies for flattening are normally applied, ~~by~~ in which recesses are filled up with SOG (Spin-On-Glass: silicon oxide film which is formed by coating and baking solution of silicon compound). Among ~~of~~ those, regarding an inorganic SOG including Si-H chemical bonds, it is disclosed in, for example, Japanese

Patent Application ~~Laying-Open~~Publication No. Hei 8-316,228 (1996).

The SOG, which is disclosed in Japanese Patent Application ~~Laying-Open~~Publication No. Hei 8-316,228 (1996)~~, however,~~ is ~~the~~ an inorganic SOG including ~~the~~ Si-H chemical bonds.~~,~~ ~~therefore~~Therefore, it ~~shows~~ has a high dielectric constant in comparison with that of an organic SOG, and ~~is easy to cause~~easily cracks due to heat.

On the other hand, ~~With the~~ an organic SOG~~, though it~~ does not have ~~such~~ the same problems ~~as~~that ~~the~~ an inorganic SOG has~~,~~. ~~on the other hand~~However, it is easy to cause a defect which is called as a "poisoned via" when a resist film is treated by a so-called ~~an~~-ashing process by using oxygen gas. ~~Especially~~ Particularly, in ~~the~~ an organic SOG, an organic group (for example, a methyl group (CH_3)) is bonded to Si, and the atomic radius of the methyl group is larger than ~~hydrogen atom~~that of a hydrogen group of ~~the~~ an inorganic SOG ~~in atomic radius thereof, therefore, it~~which causes a serious problem.

This problem will be explained~~Explaining this~~ by referring to Fig. 5 showing a method for forming a multi-layer wiring structure of the conventional art~~,~~. ~~first~~ First of all, as shown in Fig. 5 (a), after ~~being formed with~~ a lower wiring layer 101 ~~thereon,~~is formed on a substrate W, ~~the substrate W is further formed with~~ a hillock protection film 102 is formed by a CVD method. ~~Further on it, a~~As shown in Fig. 5 (b), ~~the~~ a SOG film 103 is formed on the hillock protection film 102, and thereafter, as shown in Fig. 5 (c), an upper wiring layer 104 is formed on the

SOG film 103. Further, a patterned resist layer 105 is provided as shown in Fig. 5 (d), and as shown is Fig. (e), ~~the~~ a via hole (or a through hole) 106 is formed by using the patterned resist layer 105 as a mask through an etching process on the hillock protection film 102, the SOG film 103 and the upper wiring layer 104. Next, as shown in Fig. 5 (f), the patterned resist layer 105 is removed by ~~the~~ an ashing process. Furthermore, as shown in Fig. 5 (g), conductive material 107 ~~of~~ such as aluminum is filled within the via hole 106, thereby electrically connecting between ~~them~~ the wiring layers and constructing ~~the~~ a multi-layer wiring structure.

~~And~~In this method, in a case ~~that~~ where ~~the~~ an organic SOG is ~~applied to~~used, ~~as shown in Fig. 5 (f),~~ the organic components thereof are decomposed ~~or resolved~~ when the resist layer is treated by ~~the~~ an ashing process as shown in Fig. 5 (f), and ~~the~~ a product~~ions~~ such as water~~, etc.,~~ ~~are~~ is stored within the films, thereby causing ~~the~~ a defect 108 ~~being~~ which is called as ~~the~~ a "poisoned via".

Therefore, such a method as shown in Fig. 6, in which ~~the~~ an organic SOG is used and an etching back process is ~~necessarily included therein~~required, ~~is applied~~has been employed. ~~Namely~~Specifically, as shown in Fig. 6 (a), after ~~being formed with the~~a lower wiring layer 101 is formed on a substrate W, ~~the substrate W is further formed with the~~a hillock protection film 102 is formed by ~~the~~ a CVD method, and ~~further on it is formed the~~a SOG film 103 is formed thereon. Next, as shown in Fig. 6 (b), ~~the~~ an etching back process is ~~treated~~ used for removing the organic SOG film 103 with an oxygen plasma etc. by such a

predetermined thickness ~~with an oxygen plasma, etc., thereby removing~~that the organic SOG film 103 is removed to just above the lower ~~layer~~ wiring layer 101. Thereafter, as shown in Fig. 6 (c), ~~the~~ an upper -wiring layer 104 is formed, and as shown in Fig. 6 (d), ~~the~~ a patterned resist layer 105 is formed ~~to cover on~~ over the upper wiring layer 104. As shown in Fig. 6 (e), by ~~treating with the~~conducting an etching process and ~~the~~ a subsequent ashing process ~~continuously~~, ~~the~~ a via hole 106 is formed ~~on~~ in the hillock protection ~~layer~~ film 102 and the upper wiring layer 104, ~~as well as removing~~and the resist layer is removed.~~, and further~~Further, as shown in Fig. 6 (f), ~~the~~ conductive material 107 ~~of~~ such as aluminum is filled within the via hole 106, thereby electrically connecting between the wiring layers~~them~~ and constructing ~~the~~ a multi-layer wiring structure.

By ~~treating with~~using such ~~the~~ an etching back process as shown in Fig. 6, the via hole is ~~not~~ formed in ~~a position~~an area where the organic SOG film 103 ~~is located~~does not exist, therefore, ~~such the~~a "poisoned via" will not ~~occur~~be generated.

However, in recent years, a further ~~promoted microscopic processing~~demand for miniaturization (for instance, less than or equal to 0.3 μm) ~~is~~ has been required~~, and~~. ~~if~~ If the wiring pattern is miniaturized, the thickness of the organic SOG becomes thick in an area where the wiring patterns ~~are concentrated or close to each other~~is dense, while it ~~is~~ becomes thin in an area where the wiring patterns ~~are coarse or rough~~is less dense.

~~Under such condition, i~~If the organic SOG film under such conditions is ~~etching~~ etched backed, ~~there is a disadvantage that~~

~~even~~ the wiring layer is undesirably ~~also~~ removed ~~by the etching process~~ in an area where the wiring patterns ~~are coarse or rough~~ is less dense.

SUMMARY OF THE INVENTION

For ~~dis~~solving such ~~the~~ disadvantages ~~mentioned in the above~~, in accordance with the present invention, there is provided a method for forming a multi-layer wiring structure, wherein a lower wiring layer and an upper wiring layer are electrically connected through a via hole, comprising the ~~following~~ steps of: forming an organic SOG layer directly on said lower wiring layer or ~~through~~on a predetermined film including a hillock protection layer which is formed on said lower wiring layer in advance; forming said upper wiring layer on said organic SOG layer without ~~processing~~ using ~~of~~ an etching back process; forming a via hole through an etching process by using a patterned resist layer provided on said upper wiring layer as a mask; performing an ashing process with a plasma by making ions or radicals which ~~is~~ are induced from oxygen gas as a main reactant, under an atmosphere of pressure ranging from 0.01 Torr to 30.0 Torr; and ~~burying~~ filling said via hole with conductive material so as to electrically connect ~~between~~ said lower wiring layer ~~and~~ to said upper wiring layer.

By performing ~~the~~ an ashing process with a plasma ~~of~~by making ~~the~~ ions or radicals which ~~is~~ are induced from ~~the~~ oxygen gas as ~~the~~ a main reactant under a low pressure ranging from 0.01 to 30.0 Torr, preferably, ~~by performing the ashing process under low pressure~~ ranging from 0.01 to 1.2 Torr, it is possible to

suppress ~~the~~ decomposition ~~or resolution~~ of ~~the~~ an organic group (for example, ~~the~~ a CH_3 group~~,~~ etc.) which is bonded to an Si atom of the organic SOG film, and thereby ~~as a result of this,~~ prevent ~~such the~~a "poisoned via" and so on ~~will not occur~~from being generated during the ashing process. Consequently, ~~Accordingly~~according to the present invention, ~~it can be accomplished without such the~~an etching back process is not necessary.

~~A~~The carbon content of said organic SOG layer ~~lies between~~is in the range of 5 ~~through~~ to 25 ~~in~~ atomic weight %, more preferably, between 8 ~~through~~ to 20 ~~in~~ atomic weight %. ~~Here, t~~The carbon content is ~~a scale of showing~~used to determine a ratio of ~~the~~ an organic group in ~~the~~ an organic SOG, in ~~more detail~~other words, it can be theoretically calculated from a reaction amount of ~~the~~ an alkoxysilane compound for preparing a coating -liquid of forming ~~the~~ an organic SOG, and it is ~~the~~ a ratio of ~~carbon~~ the atomic weight of carbon with respect to the total atomic weight of all elements.

If the carbon content is less than the range mentioned ~~in the~~ above, ~~since~~ the organic component is too small to thicken the film ~~or layer~~, ~~it is easy to cause the~~ thus, cracks will easily occur~~therein in addition to~~, and ~~loose~~ an inherent advantage ~~thereof,~~of an organic SOG i.e., a low dielectric constant is lost. On the other hand, if ~~it~~ the carbon content is too ~~much~~great, ~~it is not preferable since shortage occurs in~~a lack of adhesion occurs between an insulating layer which is provided on an upper layer.

criticality of carbon content

For obtaining ~~the~~ a film having the carbon content mentioned ~~in the~~ above, it is preferable to use, for example, a coating liquid containing a compound, which is obtained through hydrolysis and condensation of at least one being selected from alkoxysilane compounds in an organic solvent under existence of an acid ~~catalysis~~catalyst, said alkoxysilane compound being expressed by a general equation, $RnSi(OR^1)_{4-n}$, where R is an alkyl group ~~or an aryl group~~ ~~of~~ having a carbon number of ~~from~~ 1 to 4, ~~or aryl group~~ or aryl group, R^1 is an alkyl group ~~of~~ having a carbon number of ~~from~~ 1 to 4, and n is an integer of 1 or 2.

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~~As an~~ The following are examples of the alkoxysilane compound which is expressed by the above general equation~~, the followings can be listed~~:

(a) in a case ~~that~~ where n=1, monoalkyltrialkoxysilane including: monomethyltrimethoxysilane, monomethyltriethoxysilane, monomethyltripropoxysilane, monoethyltrimethoxysilane, monoethyltriethoxysilane, monoethyltripropoxysilane, monopropyltrimethoxysilane, monopropyltriethoxysilane, etc., and monophenyltrialkoxysilane including: monophenyltrimethoxysilane, monophenyltriethoxysilane, etc.

(b) in a case ~~that~~ where n=2, dialkyldialkoxylsilane including: dimethyldimethoxysilane, dimethyldiethoxysilane, dimethyldipropoxysilane, diethyldimethoxysilane, dimethyldiethoxysilane, diethyldipropoxysilane, dipropyldimethoxysilane, dipropyldiethoxysilane, dipropyldipropoxysilane, etc., and diphenyldialkoxy—silane including: diphenyldimethoxy-silane, diphenyldiethoxy-silane,

etc. It is necessary to use at least one kind from (a) and (b).

If desired, as another compounds which can be condensed with ~~the~~ (a) and (b), ~~in case that n=0 of the compound, namely,~~ it is also effective to use a case where n=0 of the compound which is expressed by the above general equation, namely, (c) tetraalkoxysilane~~, ---~~: including tetramethoxysilane, tetraethoxysilane, tetrapropoxysilane, tetrabutoxysilane, etc.

Among those, the compounds preferable from a practical view point are tetramethoxysilane, tetraethoxysilane, monomethyltrimethoxysilane, monomethyltriethoxysilane, dimethyldimethoxysilane, and dimethyldiethoxysilane.

It is possible to use only one of those alkoxylsilane compounds, or two or more ~~being selected from them~~in combination.

~~Concretely~~Specifically, ~~when combining~~ combination of ~~two kinds of the~~ (a) and (~~b~~c), ~~or when combining three kinds of~~combination of ~~the~~ (a), (b) and (c), ~~also when only one kind of the~~ and (a) alone are preferable.

Regarding the mol ratio of reaction in the case ~~that~~ where ~~the two kinds of the~~ (a) and (c) are combined, ~~upon~~ 1 mol of (c) tetraalkoxysilane is reacted with 0.5 - 4.0 mol, more preferably 1.0 - 2.0 mol of (a) monoalkyltrialkoxysilane~~, more preferably, by reacting 1.0 - 2.0 mol of (a),~~ and ~~thereby obtaining~~ a desirable coating -liquid containing a product obtained through hydrolysis and condensation thereof is used.

~~Further, when combining three kinds of the~~In the case where (a), (b) and (c) are combined, ~~upon~~ 1 mol of (b) dialkyldialkoxysilane ~~are~~ is reacted with 0.5 -- 4.0 mol, more

preferably 1.0 - 3.0 mol of (c) tetraalkoxysilane ~~and 0.5 - 4 mol of the (a) monoalkyltrialkoxysilane, more preferably, by reacting 1.0 - 3.0 mol of the (c)~~ and 0.5 - 4.0 mol, more preferably 0.5 - 3.0 mol of ~~the~~ (a) monoalkyltrialkoxysilane, ~~thereby obtaining~~ and a ~~desirable~~ coating -liquid containing a product obtained through hydrolysis and condensation thereof is used.

Further, in the case of ~~only the~~ (a) monoalkyltrialkoxysilane alone, ~~it is likely to obtain~~ a ~~ladder type of~~ product obtained through ~~the~~ hydrolysis and condensation easily has a ladder type structure, and ~~the~~ such a ladder type product ~~of that ladder type~~ is preferable to form a fine film.

The hHydrolysate ~~obtained with the hydrolysis can~~ may be one which is completely hydrolyzed or which is partially hydrolyzed. ~~A~~ The degree of the hydrolysis can be adjusted by an amount of water to be added, ~~therefore,~~ and the amount of water ~~to be added~~ is adjusted appropriately depending on the characteristics of the organic SOG ~~intended~~ layer to be formed. In general, it is desired that ~~upon total amount 1 mol of alkoxysilane, which is used to prepare the coating liquid, the~~ water is reacted at a ratio of 1.0 - 10.0 mol, more perferably at a ratio of 1.5 - 8.0 mol ~~thereof~~ with respect to 1 mol of alkoxysilane which is used to prepare the coating liquid. If ~~it~~ the ratio of water is too much lower than this range, the degree of hydrolysis ~~comes down to be~~ becomes low and it becomes difficult to form ~~the~~ a film~~, therefore undesirable~~. ~~Further, i~~If ~~it~~ the ratio of water is too much higher than ~~that~~ this range, ~~it is easy to occur~~ gelation ~~or gel formation, therefore, not preferable since~~ easily occurs,

which causes~~it results~~ bad stability ~~for the purpose of~~in preservation~~thereof~~.

Further, ~~with~~as for the acid~~ic~~ catalyst, ~~both~~each of organic acid ~~or~~and inorganic acid, which have been commonly used in the conventional art, can be used. As the organic acid, organic carboxylic acid ~~can be listed, including~~such as acetic acid, propionic acid, butyric acid~~, etc~~ can be used. As the inorganic acid, ~~can be listed, such as~~hydrochloric acid, nitric acid, sulfuric acid, phosphoric acid, etc. can be used.

In this case, the acid~~ic~~ catalyst is added into the coating liquid in such a manner that ~~concentration~~the concentration of acid lies within a range of 1 - 1,000 ppm, more preferably 5 - 500 ppm, or is added in a ~~form~~state of an acid~~ic~~ ~~water~~aqueous solution obtained by mixing ~~the~~acid and water to be added, and thereby ~~obtaining~~hydrolysis is performed.

The hydrolysis ~~completes the~~reaction ~~thereof~~is normally completed within 5 - 100 hours. Further, the reaction can be completed in a short reaction time ~~by heating it, at a temperature from room temperature up to 80° C and~~by ~~dropp~~adding ~~the~~an acid catalyst ~~water~~aqueous solution ~~of acidic catalyst~~into an organic solvent containing ~~the~~an alkoxysilane compound ~~for the reaction thereof~~so as to be reacted at a temperature heated from room temperature up to 80° C. The alkoxysilane compound which is hydrolyzed in this manner causes a condensation reaction, and ~~as a result thereof,~~thereby ~~it obtains~~ an ability to ~~be~~formed ~~in a form of~~ a film~~ or layer~~ is obtained.

As the organic solvent, various organic solvents which

have been commonly used in the conventional art, can be used. ~~For e~~Examples of such solvents~~, there can be listed~~ are: monohydric alcohol, including ~~such as~~ methyl alcohol, ethyl alcohol, propyl alcohol, butyl alcohol, etc.; polyhydric alcohol, including ~~such as~~ ethylene glycol, diethylene glycol, propylane glycol, etc.; a polyhydric alcohol derivative, including ~~such as~~ ethylene glycol monomethyl ether, ethylene glycol monoethyl ether, ethylene glycol monopropyl ether, ethylene glycol monobutyl ether, propylane glycol monomethyl ether, propylane glycol monoethyl ether, propylane glycol monopropyl ether, propylane glycol monobutyl ether, ethylene glycol monomethyl ether acetate, ethylene glycol monoethyl ether acetate, propylane glycol monomethyl ether acetate, propylane glycol monoethyl ether acetate, etc.; and a fatty acid, including ~~such~~ an acetic acid, a propionic acid, etc. ~~Those~~ These ~~respective~~ organic solvents can be used not only ~~one by one~~individually, but also used in combination of two or more kinds thereof~~, selecting more than 2 from them~~. ~~With~~ As for the amount of ~~them to be used~~the organic solvent, the organic solvent is used at a ratio of 10 - 30 mol ~~of them is used upon~~with respect to 1 mol of alkoxysilane.

Further, in accordance with the method for forming a ~~muiti~~multi-layer wiring structure of the present invention, ~~preferable~~ good results can be obtained with respect to ~~the~~a SOG film which is formed from a coating -liquid including polysilazane.

~~With such the polysilazane, i~~It is preferable that ~~it~~ such polysilazane ~~lies in~~has a weight-average molecular weight (Mw) in polystyrene conversion of ~~a range~~ 1500 - 5000 ~~in average~~

~~molecular weight (Mw) of polystyrene conversion, which is measured by gel permeation chromatography (GPC), in particular within a range~~more preferably 1~~,~~700 - 3~~,~~000, which is measured by gel permeation chromatography (GPC). Furthermore, it is preferable that the dispersion degree (Mw/Mn) lies within a range from 1 to 4, since it shows good stability for preservation.

In particular, since ~~the~~ polysilazane has an active organic group ~~inside~~(hydrogen ~~atom~~ which is bonded to a nitrogen atom and a silicon atom) within, ~~therefore, it is easy to cause bridge-building or chemical cross-linking~~bridge formation easily occurs and thereby ~~to~~ an increase of viscosity~~,~~ or gelation is caused. For preventing this, it is preferable to use polysilazane in which ~~be processed with hexamethyle disilazane to replace~~ a part of the active hydrogen is replaced with a trimethylsilil group by processing with hexamethyl disilazane, since it has good stability for preservation.

As ~~the~~ an organic solvent for dissolving ~~the~~ polysilazane, from view points of fire ~~fighting~~safety, dryness and stability for preservation, it is preferable ~~that it is~~to use a solvent having low ~~in hygroscopic character~~hygroscopicity. ~~As~~Examples of such a ~~compound~~ solvent~~, there can be listed, such as~~ are: dialkylether of an alkyl group ~~of~~ having a carbon number of more than 4, xylene, cyclohexane, dimethylcyclohexane, ethylcyclohexane, p-menthane, decalin, 2,2,5-trimethylhexane, dipentene, decane, isononane, octane, etc. Among ~~of those~~these, dialkylether of an alkyl group having a carbon number of more than 4 is preferable, and in particular, dibutylether is preferable.

~~These~~ These ~~respective~~ organic solvents can be used not only ~~one by-one~~individually, but also used in combination of two or more kinds thereof~~, selecting more than 2 from them~~.

The coating liquid for forming ~~the~~ an organic SOG film~~,~~ or the coating liquid containing ~~the~~ polysilazane, in accordance with the present invention, is preferable to have the above-mentioned hydrolysate of ~~the above-mentioned~~ alkoxysilane or ~~the~~ polysilazane at a concentration of 5 - 40 weight% ~~of solid body~~, more preferably 10 - 25 weight% with respect to solids, so as to achieve ~~a~~ stability for preservation and to thicken a film to be formed.

Further, in the method for forming ~~the~~ an organic SOG film, the above-mentioned coating liquid is ~~coated~~ applied onto a substrate ~~of~~ such as a semiconductor substrate, a glass substrate, a metal substrate, a ceramic substrate~~, etc.,~~ by means of a so-called ~~a~~ spinner method, a roll coating method, an immersion coating method, a spray method, a screen printing method, a brush painting method, etc., ~~and~~ it is dried to scatter or evaporate the solvent therein, and thereby ~~the~~ a coating film is formed. Then, it is baked at ~~the~~ a temperature of 250 - 500 °C, and thereby ~~the~~ an organic SOG film ~~being~~ is formed.

~~On the other hand, with~~Also, in the method for forming ~~the~~ a SOG film which is formed from ~~the~~ a coating liquid containing ~~the~~ polysilazane, ~~it is also formed in a similar manner to that mentioned in the above~~the same steps are employed.

BRIEF DESCRIPTION OF DRAWINGS

Fig. 1 (a) shows a graph of an infrared absorption spectrum ~~when being treated by~~in a case where an ashing process is performed for a predetermined time ~~period~~ under an atmospheric pressure of 1.2 Torr by using a plasma ashing apparatus of ~~leaf and~~a single wafer down-stream type~~ or model~~, and Fig. 1 (b) shows a graph of an infrared absorption spectrum ~~when being treated by~~in a case where an ~~the~~ ashing process is performed for a time ~~period~~ of 30 seconds under a predetermined atmospheric pressure by using the same apparatus;

Fig. 2 (a) shows a graph of an infrared absorption spectrum ~~when being treated by~~in a case where an ashing process is performed for a predetermined time ~~period~~ under an atmospheric pressure of 1.0 Torr by using a plasma ashing apparatus of ~~leaf and~~a single wafer down-stream ~~model~~type, and Fig. 2 (b) shows a graph of an infrared absorption spectrum ~~when being treated by~~in a case where an~~the~~ ashing process is performed for a time ~~period~~ of 30 seconds under a predetermined atmospheric pressure by using the same apparatus;

Fig. 3 (a) shows a graph of an infrared absorption spectrum ~~when being treated by~~in a case where an ashing process is performed for a predetermined time ~~period~~ under an atmospheric pressure of 0.8 Torr by using a plasma ashing apparatus of ~~leaf and~~a single wafer down-stream type, and Fig. 3 (b) shows a graph of an infrared absorption spectrum ~~when being treated by~~in a case where ~~the~~ an ashing process is performed for a time ~~period~~ of 20 seconds under a predetermined atmospheric pressure by using the same apparatus;

Fig. 4 (a) shows a graph of an infrared absorption spectrum

~~when being treated by~~in a case where an ashing process is performed for a predetermined time ~~period~~ under an atmospheric pressure of 0.01 Torr by using a plasma ashing apparatus of ~~leaf and~~a single wafer down-stream type, and Fig. ~~1~~4 (b) shows a graph of aninfrared absorption spectrum ~~when being treated by~~in a case where an ~~the~~ ashing process is performed for a time ~~period~~ of 30 seconds under a predetermined atmospheric pressure by using the same apparatus;

Figs. 5 (a) through Fig. 5 (g) show processes for flattening in accordance with ~~a~~ the conventional art; and

Figs. 6 (a) through Fig. 6 (g) show processes of etching back in accordance with ~~a~~ the conventional art.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, detailed explanations of the embodiments according to the present invention will be given by referring to the attached drawings.

(Example 1)

Preparation of Coating Liquid

~~Tetramethoxysilane of~~ 246 g (1.62 mol) of tetramethoxysilane -and ~~monomethyltriethoxysilane of~~ 220 g (1.62 mol) of monomethyltrimethoxysilane are dissolved ~~and mixed~~ into ~~propyleneglycolmonopropylether of~~ 635 g (5.38 mol) of propyleneglycolmonopropylether, and mixed. Next, a mixture of ~~purified water of~~ 194 g (10.78 mol) of deionized water and ~~nitric acid of~~ 24 ppm of nitric acid is ~~dropp~~added ~~in it~~thereinto and stirred slowly for about 5 hours. Thereafter, it is left standing still for 5 days ~~in a~~at room temperature so as to obtain a solution~~,~~

~~at 15 weight % of~~having a solids ~~state~~ concentration of 15 weight % ~~thereof~~.

~~As a coating liquid, the~~This solution ~~mentioned in the above~~ is ~~coated~~ applied onto ~~the~~ a hillock protection film covering a lower wiring layer formed on the substrate, thereby forming an organic SOG film. The carbon content in the organic SOG film which is obtained by ~~a~~ the following equation~~, and~~ is 9.4 atomic weight %:

$$C/(CH_3SiO_{3/2} + SiO_2) \times 100$$

Then, ~~on this organic SOG film is formed~~ an upper wiring layer is formed on this organic SOG film without performing ~~the~~ an etching back process, and ~~further the~~a via hole is formed with an etching process by using ~~the~~ a patterned resist layer as ~~the~~ a mask. Thereafter, with use of a plasma ashing apparatus of a ~~leaf type and a~~single wafer down-stream type, an ashing process is ~~treated~~ performed so as to remove the resist ~~film~~layer, by making ions or radicals which ~~is~~ are induced from oxygen gas as a main reactant, under an atmosphereic ~~of~~ pressure of 1.2 Torr. Thereafter, the via hole is ~~buried~~ filled with a conductive material so as to electrically connect ~~between~~ the lower ~~layer~~ wiring layer ~~and~~to the upper ~~layer~~ wiring layer.

Fig. 1 (a) shows the infrared absorption spectrums which are obtained by ~~changing~~ setting the time ~~period~~ of the above-mentioned ashing process~~, sequentially, from a curve at a top thereof, i.e.,~~ to 60 seconds, 45 seconds, 30 seconds, 15 seconds and no processing, respectively. From this drawing, it is apparent that Si-C ~~bonding~~ bonds ~~is~~ are not broken~~,~~ in the

case of the present invention.

On the other hand, Fig. 1 (b) shows the infrared absorption spectrums which are obtained ~~through the ashing process for 30 seconds by using the same plasma shing apparatus,~~ by ~~changing~~ setting the pressure of the above-mentioned ashing process~~, i.e.,~~ to 50 Torr, 40 Torr, 35 Torr and 30 Torr, respectively~~from a curve at a top thereof, sequentially, though the same condition as mentioned in the above is applied until forming the via hole by treating the etching process~~, while the time is fixed to 30 seconds. From this drawing, it is apparent that the Si-C ~~bonding~~ bonds ~~is~~ are broken and OH bonds are generated if the pressure ~~during~~ of the ashing process is high~~, and OH bonding is caused~~.

(Example 2)

Preparation of Coating Liquid

~~Tetramethoxysilane of~~ 304.~~2~~4 g (2 mol) of tetramethoxysilane, ~~monomethyltrimethoxysilane of~~ 272.4 g (2 mol) of monomethyltrimethoxysilane and ~~dimethyldimethoxysilane~~ 120.2 g (1 mol) of dimethyldimethoxysilane are dissolved ~~and mixed~~ into ~~isopropylalcohol of~~ 608.6 g (8.21 mol) of isopropylalcohol, and mixed. Next, a mixture of ~~purified water of~~ 288.0 g (16 mol) of deionized water and ~~nitric acid of~~ 40 ppm of nitric acid is ~~dropp~~added ~~in it~~thereinto and stirred slowly for about 5 hours. Thereafter, it is left standing still for 5 days ~~in a~~at room temperature so as to obtain a solution~~, at 16 weight % of~~ having a solids ~~state~~ concentration ~~thereof~~of 16 weight %.

~~As a coating liquid, the~~This solution mentioned ~~in the~~ above is ~~coated~~ applied onto ~~the~~a hillock protection film covering

a lower wiring layer formed on the substrate, thereby forming an organic SOG film. The carbon content in the organic SOG film which is obtained by ~~a~~ the following equation~~, and~~ is 14.6 atomic weight %:

$$3C/[(CH_3)_2SiO_{2/2} + CH_3SiO_{3/2} + SiO_2\cancel{)}] \times 100$$

Then, ~~on this organic SOG film is formed~~ an upper wiring layer is formed on this organic SOG film without conducting ~~the~~ an etching back process~~in the same manner as in the above~~, and ~~further the~~a via hole is formed with an etching process by using ~~the~~ a patterned resist layer as ~~the~~ a mask. Thereafter, using ~~the~~ a plasma ashing apparatus of a ~~leaf type and a~~single wafer down-stream type, an ashing process is ~~treated~~ conducted so as to remove the resist ~~film~~layer, by making ions or radicals which ~~is~~ are induced from oxygen gas as a main reactant, under an atmosphereic ~~of~~ pressure of 1.0 Torr. Thereafter, the via hole is ~~buried~~ filled with a conductive ~~body~~ material so as to electrically connect ~~between~~ the lower ~~layer~~ wiring layer and to the upper ~~layer~~ wiring layer.

Fig. 2 (a) shows the infrared absorption spectrums which are obtained by ~~changing~~ setting the time ~~period~~ of the above-mentioned ashing process~~, sequentially, from a curve at a top thereof, i.e.,~~ to 60 seconds, 45 seconds, 30 seconds, 15 seconds and no processing, respectively. From this drawing, it is apparent that the Si-C ~~bonding~~ bonds ~~is~~ are not broken, in the case of the present invention.

On the other hand, Fig. 2 (b) shows the infrared absorption spectrums which are obtained ~~through the ashing process for 30~~

~~seconds by using the same plasma ashing apparatus,~~ by ~~changing~~ setting the pressure of the above-mentioned ashing process to~~,~~ ~~i.e.,~~ 50 Torr, 40 Torr, 35 Torr and 30 Torr, respectively~~from a curve at a top thereof, sequentially, though the same condition as mentioned above is applied until forming the via hole by treating the etching process~~, while the time is fixed to 30 seconds. From this drawing, it is apparent that the Si-C ~~bonding~~ bonds ~~is~~ are broken and OH bonds are generated if the pressure ~~during~~ of the ashing process becomes high~~, and OH bonding is caused~~.

(Example 3)

Preparation of Coating Liquid

~~A solution at 10 weight % in the solid state concentration is used as the coating liquid, in which a~~ A ladder type product obtained from monomethyltriethoxysilane through ~~the~~ hydrolysis and ~~the~~ condensation under ~~the~~ existence of an acid ~~catalysis~~ catalyst is dissolved into ethanol~~.~~, and a solution having a solids concentration of 10 weight % is obtained. This ~~coating liquid~~solution is ~~coated~~ applied onto ~~the~~a hillock protection film covering a lower wiring layer on the substrate, thereby forming an organic SOG film. ~~Further, t~~The carbon content in the organic SOG film which is obtained by ~~a~~ the following equation~~, and~~ is 17.9 atomic weight %:

$$C/[(CH_3)SiO_{3/2}] \times 100$$

Then, ~~on this organic SOG film is formed~~ an upper wiring layer is formed on this organic SOG film without conducting ~~the~~ an etching back process~~in the same manner as in the above~~, and ~~further the~~a via hole is formed with an etching process by using

~~the~~ a patterned resist layer as ~~the~~ a mask. Thereafter, using ~~the~~ a plasma ashing apparatus of a ~~leaf type and a~~single wafer down-stream type, an ashing process is ~~treated~~ conducted so as to remove the resist ~~film~~layer, by making ions or radicals which ~~is~~ are induced from oxygen gas as a main reactant, under an atmosphereic ~~of~~ pressure of 0.8 Torr. Thereafter, the via hole is ~~buried~~ filled with a conductive ~~body~~ material so as to electrically connect ~~between~~ the lower wiring layer ~~wiring and~~to the upper wiring layer ~~wiring~~.

Fig. 3 (a) shows the infrared absorption spectrums which are obtained by ~~changing~~ setting the time ~~period~~ of the above-mentioned ashing process~~, sequentially, from a curve at a top thereof, i.e.,~~ to 60 seconds, 45 seconds, 30 seconds, 15 seconds and no processing, respectively. From this drawing, it is apparent that the Si-C ~~bonding~~ bonds ~~is~~ are not broken~~,~~ in the case of the present invention.

On the other hand, Fig. 3 (b) shows the infrared absorption spectrums which are obtained ~~through the ashing process for 20 seconds by using the same plasma ashing apparatus,~~ by ~~changing~~ setting the pressure of the above-mentioned ashing process~~, i.e.,~~ to 40 Torr, 35 Torr, 30 Torr and 0.01 Torr, respectively ~~from a curve at a top thereof, sequentially, though the same condition as mentioned above is applied until forming the via hole by treating the etching process~~, while the time is fixed to 20 seconds. From this drawing, it is apparent that the Si-C ~~bonding~~ bonds ~~is~~ are broken and OH bonds are generated if the pressure ~~during~~ of the ashing process becomes high~~, and OH bonding is caused~~.

(Example 4)

Preparation of Coating Liquid

~~A solution at 20 weight % in the solid state concentration is obtained by dissolving into dibutylether a~~ A product (weight-average molecular weight = 2200, number-average molecular weight = 950, dispersion = 2.3) which is obtained by adding and reacting ~~hexamethyldivilazane~~ hexamethyldisilazane ~~upon~~ with polysilazane ~~(average molecular weight=2200, average molecular number=950, dispersion=2.3),~~ is dissolved into dibutylether, and a solution having a solids concentration of 20 weight % is obtained, in which the polysilazane is composed from ingredients~~, i.e.,~~ such as ~~dichrolosilane~~ dichlorosilane and ammonia according to an ~~ordinal~~ common method. This ~~coating liquid~~solution is ~~coated~~ applied onto ~~the~~a hillock protection film covering a lower wiring layer on the substrate, thereby forming a SOG film.

Then, ~~on this SOG film is formed~~ an upper wiring layer is formed on this SOG film without conducting ~~the~~ an etching back process~~in the same manner as in the above~~, and ~~further the~~a via hole is formed with an etching process by using ~~the~~ a patterned resist layer as ~~the~~ a mask. Thereafter, using ~~the~~ a plasma ashing apparatus of a ~~leaf type and a~~single wafer down-stream type, an ashing process is ~~treated~~ conducted so as to remove the resist ~~film~~layer, by making ions or radicals which ~~is~~ are induced from oxygen gas as a main reactant, for 30 seconds, under an ~~atmosphere~~ atmospheric ~~of~~ pressure of 0.01 Torr. Thereafter, the via hole is ~~buried~~ filled with a conductive ~~body~~ material so as to electrically connect ~~between~~ the lower wiring layer ~~wiring and~~

to the upper wiring layer~~-wiring~~.

Fig. 4 (a) shows the infrared absorption spectrum after ~~treating with~~ the ashing process is conducted~~, and~~. ~~from~~ From this drawing, it is apparent that the N-H ~~bonding~~ bonds ~~is~~ are not broken~~,~~ in the case of the present invention.

On the other hand, Fig. 4 (b) shows the infrared absorption spectrum which ~~are~~ is obtained ~~through the ashing process for 30 seconds by using the same plasma ashing apparatus, under~~ by setting the atmospheric pressure of the above-mentioned ashing process ~~at~~to 35 Torr~~, though the same condition as mentioned above is applied until forming the via hole by treating the etching process~~. From this drawing, it is apparent that the N-H ~~bonding~~ bonds ~~is~~ are broken and OH bonds are generated if the pressure ~~during~~ of the ashing process becomes high~~, and OH bonding is caused~~.

As is fully explained in the above, in accordance with the present invention, decomposition ~~or resolution~~ of ~~the~~ an organic group (for example, ~~the~~ a methyl group (CH_3)~~,~~ etc.) bonded to ~~the~~ an Si atom of the organic SOG film can be suppressed, and as a result, the phenomenon ~~called~~ known as a "poisoned via" will not occur during the ashing process of the resist ~~film~~layer. Consequently, ~~it can be completed or achieved without~~ the etching back process can be omitted, and~~,~~ thereby ~~simplification of~~ the processes can be simplified~~obtained~~. Further, the ~~similar~~ same effect can be ~~obtained~~achieved ~~from~~ with respect to the SOG film which is formed from ~~the~~ a coating liquid containing ~~the~~ polysilazane.

Moreover, since the etching back process can be omitted~~it~~

~~can be completed or achieved without the etching back process~~, there is no possibility that the lower wiring layer ~~wiring~~ is removed during the etching back process, and thereby ~~being able~~ it becomes possible to ~~cope with~~form a further miniaturized pattern.

ABSTRACT OF THE DISCLOSURE

For suppressing decomposition of an organic group (for example, a CH_3 group) ~~during ashing process,~~ which is bonded to an Si atom of an organic SOG film ~~or layer~~ for use in a flattening process at the time of an ashing process, there is provided a method ~~comprises~~ comprising the ~~following~~ steps of: forming an organic SOG layer directly on a lower wiring layer or ~~through~~ on a predetermined film including a hillock protection layer which is formed on ~~said~~the lower wiring layer in advance; forming ~~said~~ an upper wiring layer on ~~said~~ the organic SOG layer without ~~processing~~ using ~~of~~an etching back process; forming a via hole through an etching process by using a patterned resist layer provided on ~~said~~ the upper wiring layer as a mask; performing an ashing process with a plasma by making ions or radicals which ~~is~~ are induced from oxygen gas as a main reactant, under an atmosphere~~of~~ic pressure ranging from 0.01 Torr to 30.0 Torr; and ~~burying~~ filling said via hole with a conductive material so as to electrically connect ~~between said~~the lower wiring layer ~~and~~ to ~~said~~ the upper wiring layer.